1055

AN OVERVIEW:

THE TOXICS DEPOSITION MONITORING NETWORK

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THE TOXICS DEPOSITION MONITORING NETWORK

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1. Introduction

The presence of persistent toxic chemicals in the Great Lakes has been a matter of environmental concern for a number of years. It has recently become apparent that direct deposition, both wet and dry, from the atmosphere, is probably a major pathway for the entry of some of these compounds to the lakes. To confirm this, and to quantify deposition fluxes to the Great Lakes, monitoring of air and precipitation borne chemicals is necessary. The Ontario Ministry of the Environment Toxics Deposition Network was designed to meet this need.

The objectives of the network are:

i) To determine the concentrations of selected toxic chemicals in air and in precipitation at regionally representative sites in the Great Lakes basin. These data will then permit an assessment of the importance of the atmosphere as a pathway for the input of toxic species to the Great Lakes.

ii) To follow a quality assurance/quality control program so that data of defined quality are produced, suitable for integration with monitoring data collected by other agencies both in Canada and the U.S.A.

This report provides an overview of the Toxics Deposition Network, including network design, sampling locations and siting criteria, instrumentation, sample collection and handling techniques, chemical analysis and data handling and analysis.

2. Network Design

To allow the MOE Toxics Deposition Network to meet its stated objectives, the design requirements are:

- a). to locate samplers on or near the shoreline of each of the Great Lakes bordering on Ontario
- b). to measure the concentrations of toxic species in both air and precipitation
- c). to monitor a list of species based on ARB and MOE priorities, and guided by international concerns.

One monitoring site has been set up on the shore of each of Lake Superior, Huron, Erie and Ontario, with a further control site located inland at Dorset. Equipment for sampling both air and precipitation has been installed at all sites.

The list of chemicals monitored in the network is based largely on the IJC target list (IJC, 1986). This list contains both metals and organic compounds. Some adjustments have been made to the list to reflect ambient levels encountered in Ontario, and the sensitivity of the analytical methods. Specifically, toxaphene was deleted from the original list, because it was consistently below the minimum amount detectable by the method. In addition, data collected in the Great Lakes basin by others confirmed that the ambient levels were substantially below the minimum amounts detectable by MOE methods. Available information indicates that toxaphene is not used in Ontario or any of the adjacent provinces or states.

At Dorset and the Toronto Islands precipitation samples are also collected for analysis for dioxins and dibenzofurans.

The list of target species for the Toxics Deposition Network is given in Table 1.

3. Network Siting Criteria and Sampling Locations

3.1 Siting Criteria

To meet the network objectives, sites on, or near, the shores of each of the Great Lakes (excluding Lake Michigan) were required. To ensure that the data are regionally representative, the monitoring sites were chosen to avoid local sources of pollutants. The criteria used in site selection were identical with those set out for the APIOS (Acidic Precipitation in Ontario Study) Daily and Cumulative networks (Chan et al., 1985a, b). The list of local sources to be avoided, as used in the site selection for those networks, is repeated below:

- urban areas (industrial activity, vehicular emissions, human activity)
- airports
- highways
- trees (obstructions, rain splash, organic debris, throughfall)
- buildings (obstructions, rain splash, emissions)
- unpaved roads (spray, salt, sand, airborne dust, vehicular emissions, snow ploughing, snow blowing)
- sewage treatment plants and aeration lagoons
- cultivated fields and orchards (herbicide and pesticide spraying, fertiliser emissions, airborne dust, organic debris)
- overhead wires
- oil or gas wells
- parking lots
- problem ground cover (rock, loose soil)
- marshes (emissions, insects)
- gravel pits
- salt or sand piles
- gardens

Consideration was given to additional factors affecting the logistics of sampler operation, both from the point of view of ease of operation, and avoidance of sample contamination:

- site characteristics (ground cover should be grassy and flat, and as open and clear as possible)
- avoidance of obstructions (adhere to a minimum sampler-to-obstruction distance of 2.5 times the obstruction height)
- surrounding vegetation (windbreaks approximately 200 metres away improve the catch efficiency of precipitation collectors)
- accessibility (easy access is required, but it is also necessary to avoid roads)
- topography (locations on or near hills or depressions should be avoided)
- electricity supply must be available on-site
- security (must be free from vandalism and/or interference with samples)
- personnel must be available to maintain the equipment and collect samples.

3.2 Sampling Locations

Application of these criteria led to the selection of three existing cumulative network sites for the installation of toxics monitoring equipment. These sites were

Port Stanley (Lake Erie)
Shallow Lake (Lake Huron)
Turkey Lake (Lake Superior)

In addition, samplers were installed at Dorset. Although this site is approximately 85 km from the nearest shoreline (Lake Huron), it was chosen because it is the main APIOS monitoring site. An APIOS technician is permanently located at Dorset, so that good quality data for QA/QC and instrument development can be best collected at this site. In addition, useful data on levels of airborne organic compounds at a rural location are collected there.

Two further sites were installed, at Point Petre on Lake Ontario, and on the Toronto Islands. This last site was specially requested to meet the needs of the Remedial Action Plan for the Toronto waterfront. It clearly did not meet the selection criteria listed above, but is included in all discussions of the network, since data from this site will also allow users to contrast the levels found in urban and rural locations.

Further development of the network is planned for 1990. The Shallow Lake site will be moved to a location near the town of Grand Bend, and a seventh site will be installed in northern Minnesota. This site will be located near the shore of Lake Superior, approximately 100 kilometres south of the Ontario-Minnesota border.

It should be noted that some compromises were necessary in site selection. It is very difficult to meet all siting requirements in Southern Ontario because the region is so heavily populated that local sources are extremely difficult to avoid. In more remote areas the opposite problem is found. Difficulties of access, and in providing electrical power and personnel severely limit the availability of suitable sites.

The locations of the Toxics Deposition Network sites are shown in Figure 1, and are listed in Table 2.

In considering the concentration and deposition of metals, data from the whole of the APIOS Cumulative Network are used. Site locations for this network are shown in Figure 1a, and are listed in Table 2a.

4. Instrumentation

Two classes of chemicals are monitored in the Toxics Deposition Network, namely metals and organic compounds. To meet the distinctly different analytical requirements it is necessary to collect separate samples for these two groups.

4.1 Precipitation Sampling

Each site is equipped with a wet-only collector for metals, a wet-only collector for organics, and a precipitation depth gauge, which is used to obtain a true measurement of precipitation depth.

The precipitation sampler for metals is a modified MIC Type A collector. This collector is used in the APIOS Cumulative Network, and has been described in detail by Chan et al. (1985b). The principal features of this instrument are :

a). sensor grids extending out from the body of the collector to detect precipitation,

b). high density polyethylene collection vessel, fitted with a sample collection bag, and

c). a hood, which is opened by an electric motor when the sensor detects precipitation, allowing the sample to be collected in the collection vessel.

This collector is illustrated in Figure 2.

Samples to be analysed for organics are collected in an MIC Type B collector (Figure 3). The operating features of this instrument are similar to those of the MIC Type A, however, the moveable hood covers a square collection funnel having an area of 0.21 square metres. This funnel is warmed in winter; liquid sample passes by gravity feed from the funnel through a cellulose filter to remove particulate matter. The sample then passes through a glass chromatographic column containing XAD-2 resin, which traps essentially all of the organic components. The effluent from the cartridge is collected in a cleaned glass jug. The entire sampler enclosure is thermostatically heated in winter, to avoid freezing, which could result in breakage of the column.

Dioxin and furan analyses are carried out on separate samples collected at the Dorset and Toronto Islands sites. MIC Type B collectors are used for this purpose, but the sample, melted if necessary, is led directly into a large glass jug, which is shipped to the laboratory. A second sampler is installed at Dorset, in which the resin cartridge method, as described above, is under evaluation for dioxin and furan sampling.

True precipitation depth is determined at each site using a Nipher shielded precipitation gauge, similar to the Atmospheric Environment Service's Nipher shielded snow gauge. During the winter (November to April) a 60%/40% mixture of methanol/ethylene glycol is placed in the gauge to melt accumulated snow. In the summer months (May to October) a capping layer of oil is placed in the gauge to minimise evaporation of the collected precipitation. The snow shield is removed for the summer months to prevent splash.

4.2 Air Sampling

Toxic species in air are sampled using filter equipment. For metals the equipment is identical with that of the APIOS Cumulative Network (Chan et al., 1985b). This is based on the Metrex Instruments Ltd. AS-2 Low-Volume Air Sampler, which contains a diaphragm pump. The flow is controlled by a rotameter, and measured by a temperature compensated dry gas meter. Digital counters record the associated total volumetric flow and operating time. This vacuum system draws air through a two-stage, 47 mm polypropylene filter pack, mounted at a height of 2 metres. The flow rate is 2 litres per minute. The equipment is illustrated in Figure 4.

Three filters are contained within the filter pack, as is shown in Figure 5. The upstream filter is a Whatman 40 cellulose filter, which traps particulate matter, including metals. The second filter is a Gelman 47 mm, 1 μm Nylon filter, which selectively absorbs nitric acid. This is followed by a pair of 50 mm Whatman 41 filters, impregnated with a potassium carbonate/glycerol solution, which absorb sulphur dioxide. The second and third stages of filtration are not required for the determination of metals, but have been retained to maintain the compatibility of the equipment with the Cumulative Network.

The sampler for organic compounds in air is based on a modified Anderson Hi Vol sampler. The air flow passes first through a Teflon coated glass fibre filter, and then through a cartridge containing approximately 45 gm XAD-2 resin. Air flow is maintained at 0.42 cubic metres per minute (15 cubic feet per minute) by a mass flow controller. The motor exhaust is led away from the sampler through a suitable hose to avoid contamination. This sampler is depicted in Figure 6.

5. Sample Collection and Handling

5.1 Precipitation Collectors

5.1.1. Metals sampling. The precipitation collector for metals is operated in accordance with the procedures of the APIOS Cumulative Network. These procedures are described elsewhere (Chan et al., 1985b). Briefly, a structured protocol is followed to minimise the possibilities for introducing contaminants into the sample. This involves removing the sampling bag from the instrument, using disposable gloves, and taking care not to touch any sampling surfaces. The instrument is then cleaned, prior to the installation of a new sampling bag. The operation of the instrument is checked, and an accurate precipitation depth measurement is made. As part of the quality assurance program, all information pertinent to the sample and conditions at the site are noted in an operator log book, and on an operator field sheet. The field sheet accompanies the sample. This information is used if inconsistencies of sampler performance, or problems affecting sample integrity are found or suspected.

Samples are shipped in coolers to the laboratory, where they are kept at 4 °C until analysed.

5.1.2. Organics sampling.

Sample collection and handling procedures for organics in precipitation have been described in detail by Shackleton (1990). They may be summarised as follows. The sampler is shut off, and a check made that all precipitation has drained from the collection funnel. The flow control valve below the resin column is closed, and the tubing below the column drained into the effluent bottle. The resin column is removed and capped off for shipping, and the filter pack is also removed and packaged for shipping. The instrument is then cleaned, with particular care being given to the collection surface of the funnel, and the underside of the hood.

A replacement filter assembly, column and effluent bottle are then installed. The sampling train is flushed with methanol then distilled water, and the flow rate is set. It is very important to remove air bubbles from the sampling train, and to set the flow rate fast enough that precipitation does not back up excessively. An hydraulic head is created by looping the drain tubing above the filter assembly, thus ensuring that the resin column does not dry out.

Resin cartridges for dioxin and furan analysis are handled in the same way. Jug samples are removed from the sampler, the neck of the jug is sealed with cleaned aluminium foil, and the jug is submitted for analysis.

The samples are shipped to the laboratory in coolers. It has been found that cooling in transit is not necessary, but the coolers provide a convenient impact-cushioning container. Sampler operation is checked, and the field sheet and log book are completed.

Problems can potentially occur during winter time power failures, when the contents of the resin cartridge could freeze, cracking the container, and leading to loss of sample. Experience has shown that the number of samples lost due to this cause has been small.

5.2 Air Sampling

5.2.1 Metals sampling. The collection and handling of filter pack samples for metals follows the protocol set down for the APIOS Cumulative Network (Chan et al., 1985b). On changeover days the low volume sampler is shut off. The associated flow rate, flow volume and total time are recorded on the field sheet, together with any observations pertinent to sampler operation or sample integrity. The exposed filter pack is covered with a new "Whirl-Pak" bag, and screwed off the threaded base, and the bag is sealed. The reverse of this procedure is followed to mount the new, unexposed filter pack. The digital counters on the low volume sampler are reset to zero, and the unit is switched on again.

The exposed filter pack is unloaded in the MOE Regional Office. The Whatman 40, Nylon and impregnated Whatman 41 filters are stored in separate extraction vials, which are capped, labelled and shipped to the laboratory.

5.2.2 Organics sampling. Sample collection and handling for organics in air are as described by Shackleton (1990). The flow rate of the instrument is checked and recorded, using a manometer and a calibrated orifice which is placed over the filter holder. The filter is removed and sealed in clean aluminium foil, and the exposed resin cartridge is then also removed. The exposed cartridge is sealed using the shipping caps from the clean cartridge, which is then installed. The new filter is then put in place and the flow rate is rechecked. The mass flow controller is adjusted if necessary, to return the flow rate to 0.42 cubic metres per second.

All pertinent information is entered on the field sheet, and in the log book, and the timer is reset so that sampling starts at the correct time. The high volume sampler is run for four days every second week, from 8 a.m. Monday. This is different from all other samplers in the Toxics Deposition Network, which are run on a 28-day cycle, with no interruption between sampling periods, except for that required to change the samples.

6. Chemical Analysis

6.1 Precipitation Samples

6.1.1 Metals samples. From an operational point of view, the samplers at toxics monitoring sites are treated as belonging to the APIOS Cumulative Network, and the analytical procedures for that network are followed. In addition to sample volume and the metals zinc, iron, nickel, copper, lead, aluminium, cadmium, manganese, vanadium and arsenic, the following "traditional" parameters are also determined: conductivity, pH, total acidity, sulphate, nitrate, ammonium, chloride, calcium, magnesium, sodium, potassium, total Kjeldahl nitrogen and total phosphorous. The analytical methods are summarised in Table 2.

6.1.2 Organics. Filters are extracted with acetone, which is then back extracted with dichloromethane. The resin is eluted with acetone, which is also back extracted with dichloromethane. A second elution of the resin is carried out with dichloromethane. This eluent is combined with the back extractant. The resulting dichloromethane solutions are dried and evaporated down to 1 ml, and are then fractionated by florosil column chromatography. The target compounds are found in the first two fractions, which are analysed by dual capillary, electron capture gas chromatography.

Liquid dioxin and furan samples from jug sampling are extracted with pentane, and the cartridges and filters are extracted with hexane and toluene respectively. All extracts are cleaned up on open, multi-layer columns, and then concentrated almost to dryness. The concentrate is made up to a fixed volume (usually 10 microlitres) and analysed by GC/MS/MS (gas chromatography, followed by a two stage mass spectrometer).

6.2 Air Samples

6.2.1 Metals. The individual filters are analysed as follows:

- the Whatman 40 filter is extracted with deionised-distilled water, and analysed for metals (Zn, Fe, Ni, Cu, Pb, Al, Cd, Mn, V, As) as well as SO_4^{2-}, NO_3^-, NH_4^+, Cl^- Na^+, and K^+.

- the nylon filter is extracted with sodium hydroxide, and analysed for nitrate (from nitric acid) and sulphate (believed to result mostly from the fraction of sulphur dioxide absorbed by these filters).

- the pair of impregnated Whatman 41 filters is extracted in hydrogen peroxide, and analysed for sulphate (produced by oxidation of the absorbed sulphur dioxide).

The methods of analysis are summarised in Table 3.

6.2.2 Organics. The filter and the resin cartridge are separately extracted with dichloromethane, and are then analysed as was described for the precipitation samples, in Section 6.1.2.

7. Data Handling and Analysis

After approval by laboratory management, data are entered from the Laboratory Information System (LIS) into the Ministry's Sample Information System (SIS) data base, and are then retrieved into a separate file. Supporting field data, from the field sheet, such as flow volume, precipitation depth, sampling date, etc., are merged with the analytical data in this file. Before the results are finalised the data are screened and validated. Apart from detailed manual checks for omissions and obvious inconsistencies, statistical tests for outliers are applied. These include Dixon-ratio tests, and checks for exceedence of range. In addition a number of tests of internal consistency are possible for ions in precipitation, including ion balance (anion to cation), and comparison of measured and predicted conductivity and pH.

Reports are issued annually containing listings of the data, and statistical summaries. Detailed interpretations and special analyses are also produced on a regular basis.

8. References

Chan, W.H., Orr, D.B., Bardswick, W.S. and Vet, R.J. (1985a), An Overview: The Event Wet/Dry Deposition Network (1st Revised Edition). Ontario Ministry of the Environment Report ARB-142-85-AQM.

Chan, W.H., Orr, D.B., Bardswick, W.S. and Vet, R.J. (1985b), An Overview: The Cumulative Wet/Dry Deposition Network (2nd Revised Edition). Ontario Ministry of the Environment Report ARB-141-85-AQM.

IJC (1986), Summary Report of the Workshop on Great Lakes Atmospheric Deposition, Scarborough, Ontario, October 1986.

Shackleton, M.N., (1990), Technical and Operating Manual: Organics Deposition Monitoring Program. Ontario Ministry of the Environment Report (In Press).

Table 1. List of Target Species for Toxics Deposition Network

- PCB (total and congeners)
- Hexachlorobenzene
- Heptachlor
- Aldrin
- DDT (plus metabolites and degradation products)
- Mirex
- Hexachlorocyclohexane (α, β and γ)
- Chlordane (α and γ)
- Oxychlordane
- Dieldrin
- Endrin
- Metals, including cadmium, lead and arsenic
- Polychlorinated dibenzodioxins
- Polychlorinated dibenzofurans

Table 2. Toxics Deposition Network Site Descriptions

Station Name	Number	Elevation (m above MSL)	Latitude (North)	Longitude (West)	UTM Grid Coordinates (Northing)	(Easting)
Port Stanley	1061	213	42°40’22"	81°09’55"	4724050	486700
Shallow Lake	1091	229	44°34’54"	81°05’24"	4936200	492850
Dorset	3011	320	45°13’26"	78°55’52"	5009650	662400
Toronto Islands	3201	75	43°36’50"	70°79’22"	4830044	662418
Point Petre	4161	75	43°50’20"	77°09’10"	4856015	326929
Turkey Lake	5141	472	47°03’15"	84°24’00"	5214250	696750

Table 2a. APIOS Cumulative Deposition Network Site Description

Station Name	Number	Elevation (m above MSL)	Latitude (North)	Longitude (West)	UTM Grid Coordinates (Northing)	(Easting)
Colchester	1041	183	41°59'15"	82°55'41"	4650000	340300
Merlin	1051	191	42°14'47"	82°13'30"	4676400	398950
Pt. Stanley	1061	213	42°40'22"	81°09'55"	4724050	486700
Shallow Lake	1091	229	44°34'54"	81°05'24"	4936200	492850
Palmerston	1101	389	43°48'19"	80°54'12"	4850050	507750
Huron Park	1191	250	43°17'28"	81°30'03"	4793000	459350
Dorset	3011	320	45°13'26"	78°55'52"	5009650	662400
Campbellford	3081	175	44°17'28"	77°47'33"	4907600	277150
Coldwater	3101	280	44°37'31"	79°32'08"	4942200	615900
Smith Falls	4061	122	44°56'41"	75°57'48"	4977100	423950
Golden Lake	4081	160	45°36'48"	77°12'03"	5053200	328400
McKellar	5011	244	45°30'57"	79°55'19"	5040600	583950
Killarney	5021	183	45°59'26"	81°29'18"	5092900	462200
Mattawa	5031	198	46°16'45"	78°49'19"	5127150	667800
Gowganda	5061	343	47°39'04"	80°46'32"	5277300	516600
Moonbeam	5071	244	49°19'16"	82°08'46"	5463600	416650
Turkey Lake	5141	472	47°03'15"	84°24'00"	5214250	696750
Moosonee	5161	8	51°12'34"	80°42'20"	5673000	520550
Dorion	6011	244	48°50'33	88°36'45"	5410800	382150
Pickle Lake	6041	360	51°27'41"	90°12'04"	5704800	694550
Quetico Centre	6071	420	48°44'24"	91°12'08"	5399750	632100
E.L.A.	6091	123	49°39'22"	93°43'28"	5500950	447350
Geraldton	6121	351	49°48'05"	86°46'00"	5516300	516750

Table 3. APIOS Cumulative Wet Sample Laboratory Analyses

Parameter	Analysis Method	Detection Limit (mg L^{-1})
pH (for H_f* determination)	Radiometer pH meter and Ingold low-conductivity combination pH electrode.	0.01 pH units
Total acidity (for H_t determination)	Gran titration: NaOH titration to a series of inflection points; results presented as μg L^{-1} as H^+	0.01
Conductivity	Radiometer conductivity cell and meter	0.1 μS cm^{-1}
SO_{4}^{2-}	Ion chromatography	0.05
N-NO_3^-	Ion chromatography	0.01
Cl^-	Ion chromatography	0.01
N-NH_4^+	Automated phenate-hypochlorite colourimetry	0.005
Ca^{2+}	Flame atomic absorption	0.01
Na^+	Flame atomic absorption	0.005
K^+	Flame atomic absorption	0.005
Mg^{2+}	Flame atomic absorption	0.005
N-TKN (total Kjeldahl nitrogen)	Automated phenate-hypochlorite colourimetry	0.06
TP (total phosphorous)	Ammonium molybdate ascorbic acid colourimetry	0.006
Zn	ICP/mass spectrometry	0.001
Fe	ICP/mass spectrometry	0.001
Ni	ICP/mass spectrometry	0.0002
Cu	ICP/mass spectrometry	0.0002
Pb	ICP/mass spectrometry	0.001
Al	ICP/mass spectrometry	0.005
Cd	ICP/mass spectrometry	0.00002
Mn	ICP/mass spectrometry	0.001
V	ICP/mass spectrometry	0.0004
As	ICP/mass spectrometry	0.0004

* H_f - Free hydrogen ion concentration, H_t - Total hydrogen ion concentration

Table 4. APIOS Cumulative Low-Volume Air Filter Laboratory Analyses

Parameter	Filter Type	Extraction Method	Analysis Method	Detection Limit (μg filter^{-1})
Zn	Whatman 40	20 minute ultrasonic bath in 50 ml deionised/distilled water, followed by oven digestion in 5% HNO_3	ICP/mass spectrometry	0.050
Fe	Whatman 40	Same as above	ICP/mass spectrometry	0.050
Ni	Whatman 40	Same as above	ICP/mass spectrometry	0.010
Cu	Whatman 40	Same as above	ICP/mass spectrometry	0.010
Pb	Whatman 40	Same as above	ICP/mass spectrometry	0.050
Al	Whatman 40	Same as above	ICP/mass spectrometry	0.250
Cd	Whatman 40	Same as above	ICP/mass spectrometry	0.001
Mn	Whatman 40	Same as above	ICP/mass spectrometry	0.050
V	Whatman 40	Same as above	ICP/mass spectrometry	0.020
As	Whatman 40	Same as above	ICP/mass spectrometry	0.020
SO_4^{2-}	Whatman 40	Same as above	Ion chromatography	2.00
$N\text{-}NO_3^-$	Whatman 40	Same as above	Ion chromatography	0.50
$N\text{-}NH_4^+$	Whatman 40	Same as above	Automated phenate-hypochlorite colourimetry	0.250
Cl^-	Whatman 40	Same as above	Ion chromatography	0.50
Ca^{2+}	Whatman 40	Same as above	Flame atomic absorption	1.0
Mg^{2+}	Whatman 40	Same as above	Flame AA	0.025
Na^+	Whatman 40	Same as above	Flame AA	0.25

Table 4. APIOS Cumulative Low-Volume Air Filter Laboratory Analyses (cont)

Parameter	Filter Type	Extraction Method	Analysis Method	Detection Limit (μg filter^{-1})
K^+	Whatman 40	20 minute ultrasonic bath in 50 ml deionised/distilled water followed by oven digestion in 5% HNO_3	Flame AA	0.250
N-HNO_3	Nylon	20 minute ultrasonic bath in 25 ml 3×10^{-3} N NaOH	Ion chromatography (as NO_3^-)	0.25
SO_2	Nylon	Same as above	Ion chromatography (as SO_4^{2-})	1.0
SO_2	Whatman 41	60 minute shaking in 50 ml 0.05% (v/v) hydrogen peroxide, followed by 20 minute ultrasonic treatmnet, followed by making up to 50 ml with hydrogen peroxide	Ion chromatography (as SO_4^{2-})	1.65

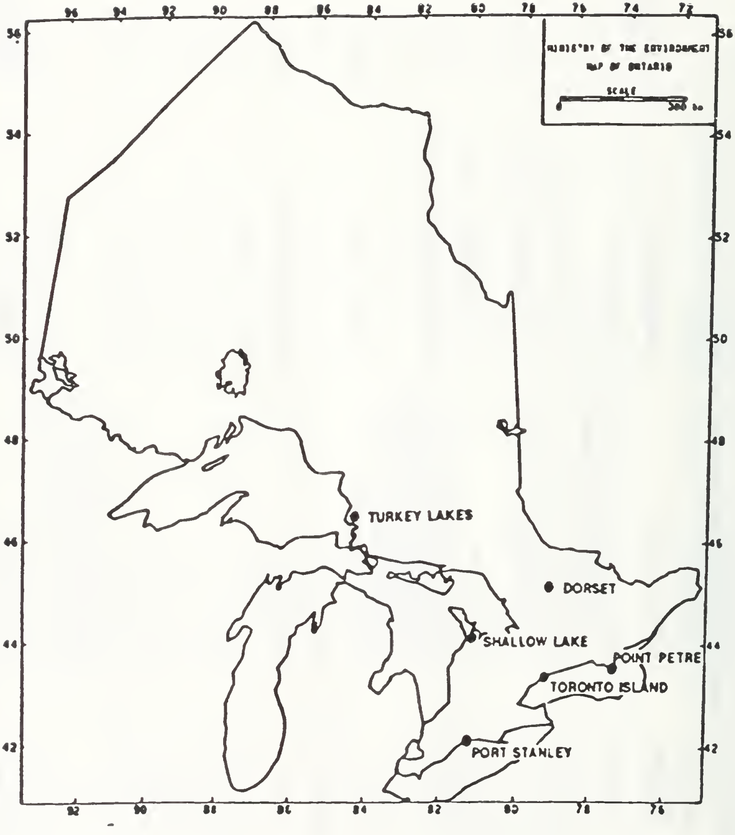
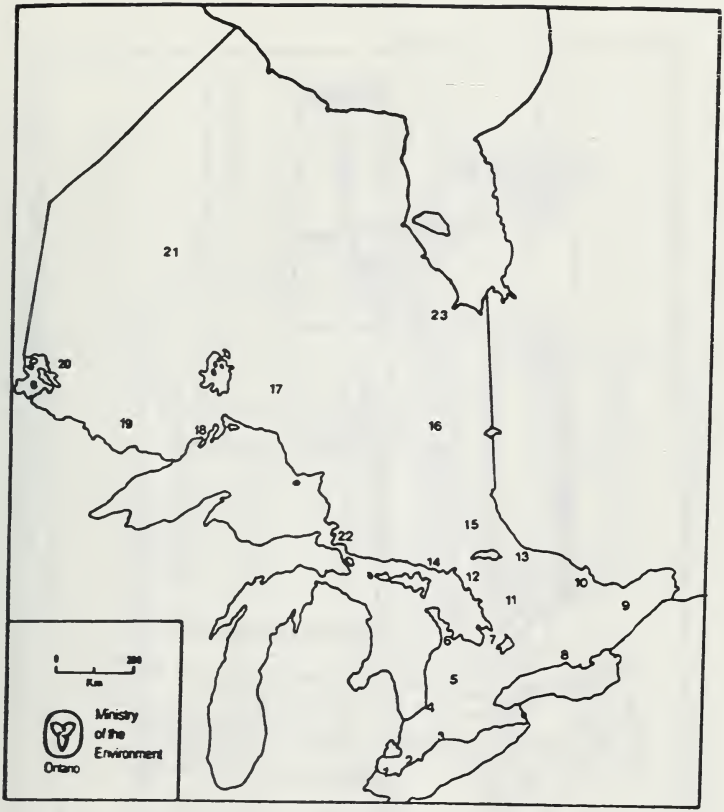


Figure 1. Toxics Deposition Monitoring Network site locations



1. Colchester
2. Merlin
3. Pt. Stanley
4. Huron Park
5. Palmerston
6. Shallow Lake
7. Coldwater
8. Cambellford
9. Smith's Falls
10. Golden Lake
11. Dorset
12. McKellar
13. Mattawa
14. Killarney
15. Gowganda
16. Moonbeam
17. Geraldton
18. Dorion
19. Quetico Centre
20. Experimental Lakes Area
21. Pickle Lake
22. Turkey Lake
23. Moosonee

Figure 2. APIOS Cumulative Monitoring Network site locations

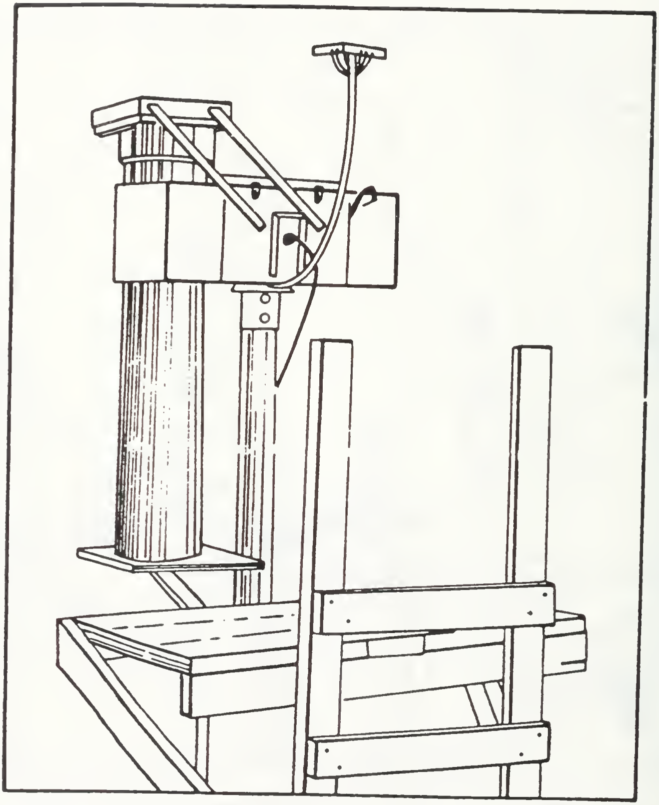


Figure 3. MIC Type A wet-only collector, used for monitoring metals in precipitation.

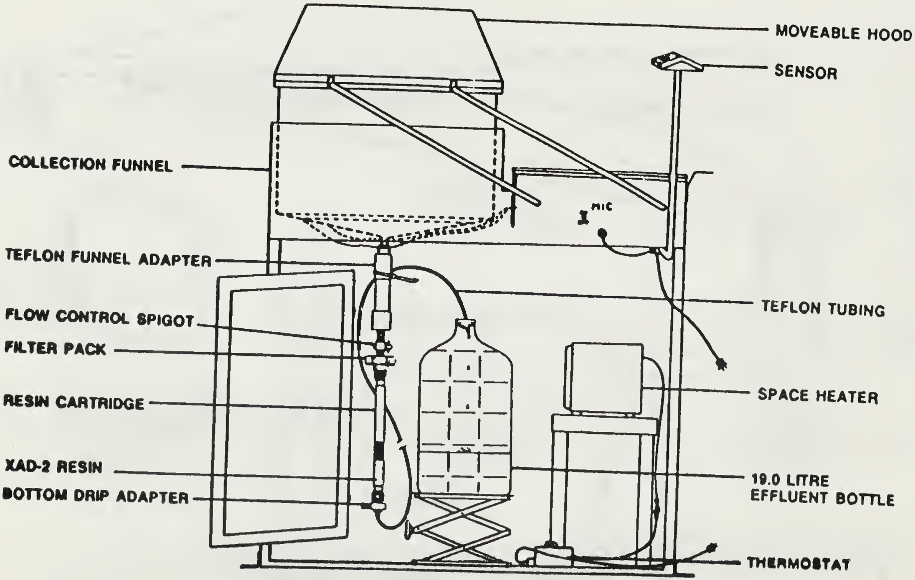


Figure 4. MIC Type B wet-only collector, used for monitoring organics in precipitation.

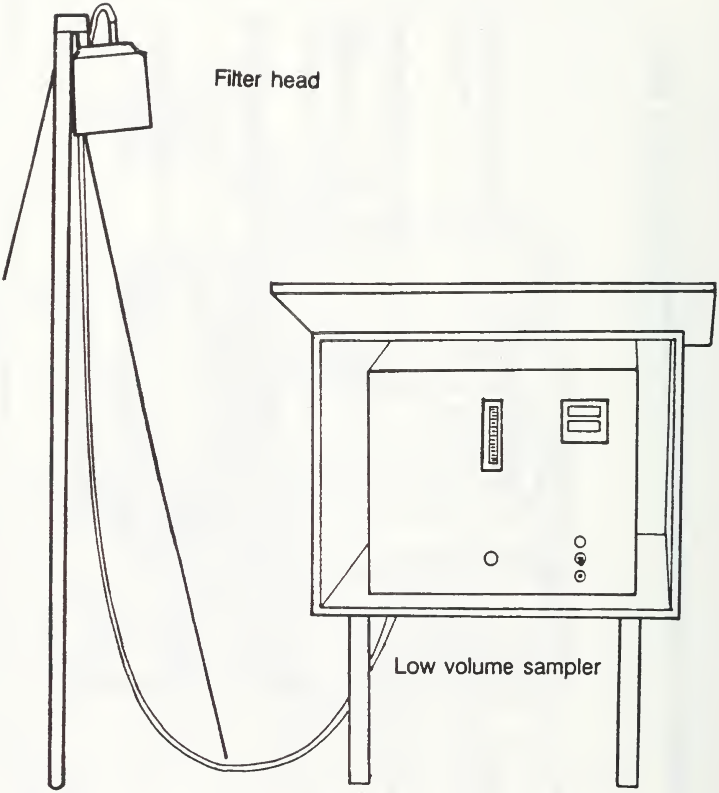


Figure 5. Low volume air sampling equipment for metals.

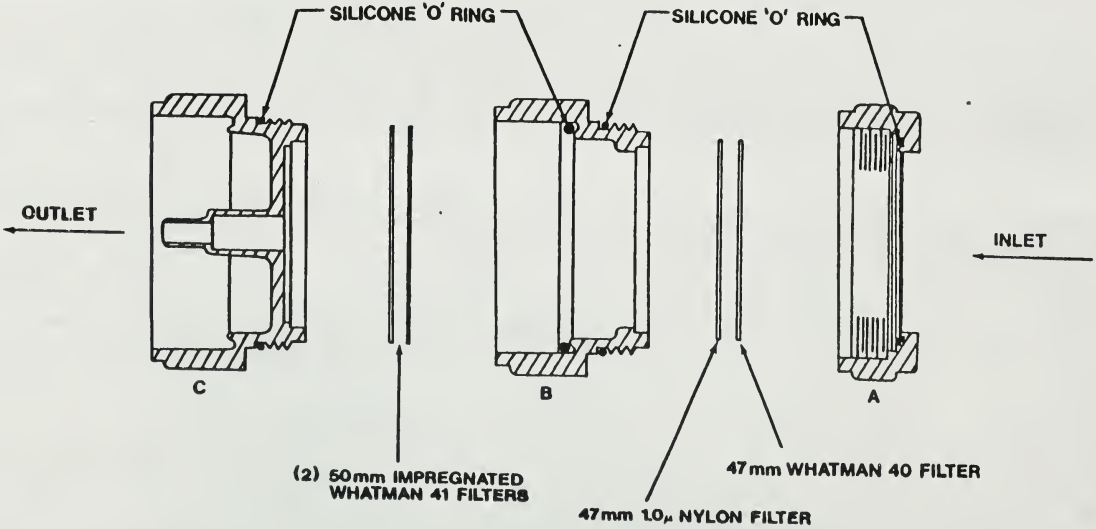


Figure 6. Filter pack used in the low volume air sampling system.

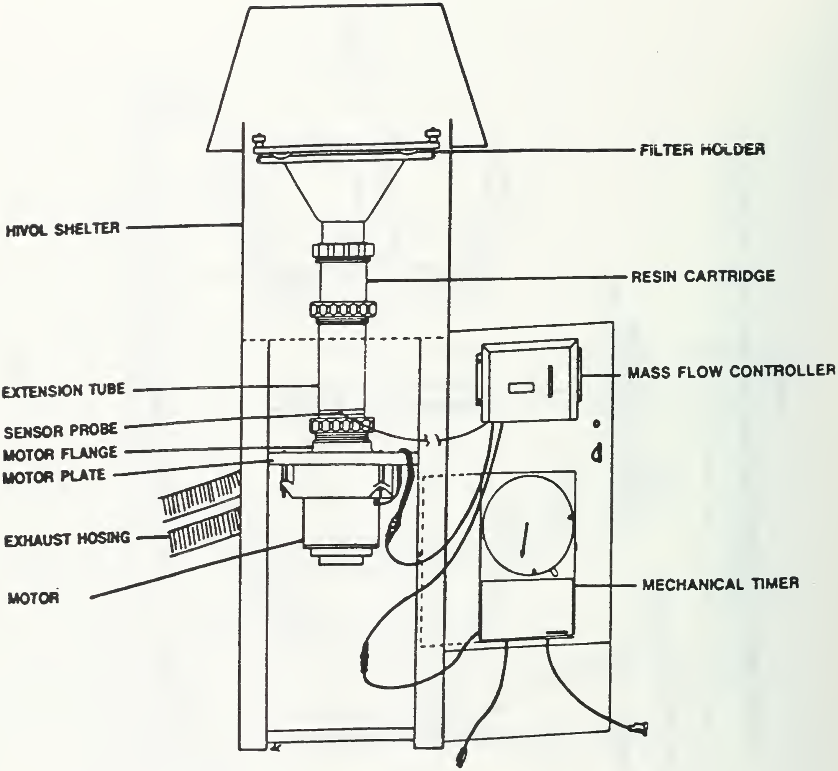


Figure 7. High volume air sampler for organic species.